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(54) **Overcurrent protection device.**

(57) An overcurrent protection device 10 has a fixed 26 and a movable 32 contact electrically connected to a pair of terminals 14, 16 and a snap acting bimetallic member 34 which is responsive to a thermally resistive element 28, connected in series with the contacts between the terminals to cause the contacts to move from an engaged position to a disengaged position. The device further includes a current bypass path 24 adapted to be connected in parallel with the thermally resistive element 28 and a second thermally responsive bimetal member 24b to cause the electrical connection. Additionally, a heater block 18 can be provided between the terminals 14, 16 which has a resistance significantly higher than that of the thermal resistive element 28.

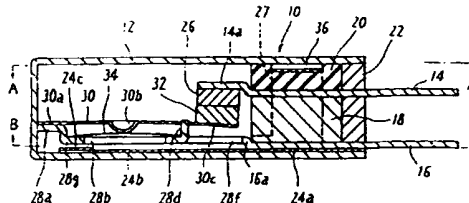


FIG. 1.

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## Background Invention

This invention relates to an overcurrent protection device, and more particularly to an overcurrent protection device for protecting electrical appliances from overcurrent.

In motor driven electrical machines and devices when moving parts are clogged and stop due to the accumulation of dust and ice, or the action of outside forces, overloading occurs which causes a current flow much higher than the rated value with the consequence that coils or other parts may burn. As is known in the art and shown in Figure 13, an overcurrent protection device P is placed in the current sourcing circuit of the electrical machine, such as a motor M, and this overcurrent protection device P can cut off the circuit when the current becomes higher than a prescribed level.

In the prior art, a current-type fuse was used as this type of overcurrent protection device P. As shown in Figure 14 for motor M, which has a rated operating current of  $I_R$ : if the motor "locks up" at time  $t_1$  and becomes overloaded, overcurrent  $I_L$  flows and the resulting heat opens current-type fuse P, and the electrical current in the circuit is cut off. In this way, as current-type fuse P cuts off the electric circuit, electric motor M is protected. A major drawback, however, with the use of a current-type fuse is the fact that each time the electric circuit is cut off, a new current-type fuse must be installed, a rather tedious process for the user.

A thermostat and temperature-type fuse may be used as a means to replace the current-type fuse. Such devices can detect overheating of an electrical machine and then cut off the electric circuit. However, with conventional thermostats, after the electric circuit is cut off, the electric circuit often is closed (reconnected) again whether or not the aforementioned electric machine has sufficiently cooled. Consequently, there can be a cycling overcurrent flow situation which is a problem. In addition, faulty operation may take place when the surrounding temperature rises, although no current actually flows. For the temperature-type fuse, just as in the case of the current-type fuse, each time the electric circuit is cut off, a new fuse must be installed. This, of course, is an inconvenience.

## Summary of the Invention

The purpose of this invention is to solve the problems of the conventional type protection devices by providing an overcurrent protection device characterized by the fact that there is no need to replace the overcurrent protection device each time the electric circuit is cut off due to the fact that it has a self-holding function which enables it to maintain the cutoff state after the overcurrent condition has been detected.

Another purpose of this invention is to prevent the faulty cutoff of the electric current when the current flow in the machine being protected is at an acceptable rated current flow.

Accordingly, an overcurrent protection device of this invention comprises a fixed contact electrically connected to a first terminal, a movable contact connected to a second terminal adapted to engage and disengage with the fixed contact, a thermally resistive element connected in series to the fixed and movable contacts between the first and second terminals, a thermally responsive snap-acting first bimetal member positioned near said thermal resistive element which moves from a first position to a second position upon being heated to a first prescribed temperature, said second position causing the disengagement of said movable and said fixed contacts, a current bypass means adapted to be connected in parallel with said thermally resistive element, and a second thermally responsive bimetal member positioned near said thermal resistive element adapted to electrically connect said current bypass means in parallel with said thermal resistive element when heated to a second prescribed temperature lower than the first prescribed temperature associated with the first bimetal member.

With the overcurrent protection device, when the rated current flows in the machine/motor, the temperature in the vicinity of the thermal resistive element rises, due to the accumulation of heat and/or rise in ambient temperature. Upon such temperature reaching a prescribed level, the second bimetal member functions to connect the current bypass means in parallel with the thermal resistive element. In this way, the resistive heating rate of the thermal resistive element is reduced and the heating effect on the first bimetal member is suppressed. Consequently, in the case of rated current operation, there is no faulty operation in which the fixed and movable contacts are opened. On the other hand, when current surges are encountered, the heating rate of the thermal resistive element does provide the predetermined temperature to the first bimetal member to activate and open the contacts. In this way, the overcurrent is cut off and burning of the electrical machine or part is prevented.

In accordance with a second aspect of this invention, an overcurrent protection device comprises a fixed contact electrically connected to a first terminal, a movable contact connected to a second terminal adapted to engage and disengage with the fixed contact, a thermally snap-acting first bimetal member positioned near said thermal resistive element which moves from a first position to a second position causing the disengagement of said movable and said fixed contacts, a current bypass means connected in parallel with said thermally resistive element adapted to electrically connect said current bypass means in parallel with said thermal resistive element when heated

to a prescribed temperature, and a heating means adjacent said first bimetal member connected between the first and second terminals, said heating means having a resistance significantly higher than that of said thermal resistive element.

In accordance with this second device, upon the opening of the contacts the current (now at a very low level) flows through the high resistance heating block which supplies heat sufficiently to the first bimetal member to keep it in the inverted state (contacts open). This self-holding (contacts open) state can be released when the system switch external to the protector is opened so no voltage is applied between the two terminals of the protector.

#### Description of the Drawings

Other objects, advantages and details of the overcurrent protection device of this invention appear in the following detailed description of the preferred embodiments of the invention, the detailed description referring to the drawings in which:

Figure 1 is a cross-sectional view illustrating the overall configuration of the overcurrent protection device of the present invention;

Figure 2 is a planar view cut along line A-A in Figure 1;

Figure 3 is a bottom view cut along line B-B in Figure 1;

Figure 4a is a top view illustrating the configuration of the fixed bracket of the overcurrent protection device of Figure 1;

Figure 4b is a cross-sectional view cut along line C-C of Figure 4a;

Figure 5a is a top view of the second bimetallic member of the overcurrent protection device of Figure 1;

Figure 5b is a left side view of Figure 5a;

Figure 5c is cross-sectional view cut along line D-D in Figure 5a;

Figure 6a is a side view of leaf spring (36) of the overcurrent protection device of Figure 1;

Figure 6b is a top view of Figure 6a;

Figure 7 is an electric circuit diagram with the overprotection device of Figure 1 and illustrating the state before and immediately after the power source is turned on;

Figure 8 is a cross-sectional view illustrating the state of normal rated operation of the overcurrent protection device of the present application;

Figure 9 is an electric circuit diagram similar to Figure 7 but illustrating the state of normal rated operation of the overcurrent protection device;

Figure 10 is a cross-sectional view illustrating the contacts in the open, cut-off state of the overcurrent protection device of the present invention;

Figure 11 is an electric circuit diagram similar to Figure 7 illustrating the cut-off state of the over-

current protection device;

Figure 12 is a timing diagram illustrating the operation of the overcurrent protection device of Figure 1;

Figure 13 is a typical electric circuit diagram of an overcurrent protection device of the prior art; and Figure 14 is a timing diagram illustrating the function of a prior art current-type fuse overcurrent protection device.

#### Detailed Description of the Preferred Embodiments

Overcurrent protection device 10 as shown in Figure 1 has a cylindrical housing 12 made of aluminum or the like. The overcurrent protection mechanism of device 10 is generally contained within housing 12. From the bottom of housing 12 (right end in Figure 1) two terminals 14, 16 made of brass or the like extend outwardly. The bottom of the housing 12 has an opening which contains a heating block 18 made of an electroconductive material such as an electroconductive phenol and an insulation 20 typically made from a conventional phenol. Additionally, an epoxy adhesive 22 is used to seal the housing from the outer side. First terminal 14 is held between heating block 18 and insulator 20, and second terminal 16 and a base portion 24a of a second bimetal member 24 (discussed further below) are held between heating block 18 and the side surface of housing 12.

On the inside of housing 12, a fixed contact 26 made of, for example, a silver alloy, is fixed on a base portion 14a of first terminal 14. A thermal resistive element 28 typically metallic is also contained within housing 12 extending from base portion 16a of second terminal 16 toward the closed end of housing 12. On a tip portion 28a of thermal resistive element 28, a base portion 30a of a movable arm 30 is attached as by welding. Movable arm 30 is made from a resilient electrically conductive material such as beryllium copper. At the distal end 30c of arm 30 a movable contact 32 made of, for example, a silver alloy is fixed directly opposite fixed contact 26, and as shown in Figure 1, in engagement with fixed contact 26.

Accordingly, second terminal 16 and thermal resistive element 28 forms an integrated bracket member. The configuration of the fixed bracket member will be explained below with reference to Figures 4a and 4b. Figure 4a is a top view of this fixed bracket and Figure 4b is a cross-sectional view cut along line C-C of Figure 4a. In Figure 4a, a circular opening 28b is formed at the central portion of thermal resistive element 28. Adjacent one portion of this opening 28b, a tip portion 28a of thermal resistive element 28 forms stepwise wall portion 28c. On the opposite side of opening 28b from wall portion 28c is a small wall portion 28d which protrudes upward and also side wall portions 28e on the side edge of the thermal resistive element 28 are provided. By means of these

four wall portions 28c, 28d, 28e, 28f, the configuration and location of temperature responsive first main bimetallic member 34 (to be explained below) is defined. On the thermal resistive element 28, a U-shaped opening 28f is placed in the vicinity of protruding wall portion 28d. Due to this opening 28f, since the area of thermal resistive element 28 is reduced, the resistance of thermal resistive element is increased; and thus, the rate of resistive heating of the thermal resistive element in this area is increased. A part 27 extending in a direction generally perpendicular to second terminal 16 at one end of side wall portion 28e is a pressing plate for fixing heating block 18 and insulator 20 to the fixed bracket.

As shown in Figure 1, a first main bimetallic member 34 of a generally circular shape is set on circular opening 28b of thermal resistive element 28. The sides of bimetallic member 34 are surrounded by the four walls 28c, 28d, 28e, 28f of the fixed bracket so that it is generally fixed in the transverse direction. In addition, member 34 is always contacted and pressed from the upper side by a semispherical protrusion 30b of movable arm 30. As shown in Figure 2, in movable arm 30, an opening 30d is arranged for passage through the small wall portion 28d of the fixed bracket.

On the lower side (inner side) of thermal resistive element 28, movable portion 24b of second bimetal member 24 is positioned parallel to thermal resistive element 28. This bimetal member can be made from conventional bimetal materials. As shown in Figure 5, it has a nearly rectangular shape with a convex shaped contact portion at its tip or distal end. In this embodiment, second bimetal member 24 also plays the role of a current bypass means.

As shown in Figure 1, sheet 36 arranged on insulator 20 is a leaf spring made of, for example, stainless steel. As shown in Figure 6a, this leaf spring 36 is originally a bent sheet. However, when the tip of pressing sheet 27 of the fixed bracket moves, leaf spring 36 is held and pressed on insulation 20, and the leaf spring 36 is deformed to the flat shape as shown in Figure 6b and Figure 1. By means of the reactive force (the elastic recovery force) of this leaf spring 36 deformed to the flat shape, heating block 18 is held between first and second terminals 14, 16 with sufficient pressure. In this way, a good electrical contact can be made.

With reference to Figures 1 and 7-12, the function of the overcurrent protection device of this embodiment will be explained. Figure 1 shows the state of this overcurrent protection device 10 before and immediately after the power source is turned on. Figure 7 is a circuit diagram corresponding to the state shown in Figure 1. Figure 8 shows the state of this overcurrent protection device when normal rated current flows. Figure 9 is the electric circuit diagram corresponding to the state shown in Figure 8. Figure 10

shows the state of this overcurrent protection device 10 after cut off (contacts are open). Figure 11 is an electric circuit diagram corresponding to the state shown in Figure 10. In Figures 7, 9 and 11, E represents a DC power source, Sw represents a manual system switch, M represents an electrical machine or device, such as a DC motor, R represents the resistance of heating block 18, and r represents the resistance of thermal resistive element 28. Figure 12 shows a timing diagram illustrating the operation of this overcurrent protection device 10. This overcurrent protection device 10 is placed near motor M.

Before system switch Sw is closed, in this overcurrent protection device 10, as shown in Figure 1, main bimetal 34 is in its original state, that is, in the state of being bowed upwardly; hence, movable arm 30 is positioned upwardly, and movable contact 32 is pressed into contact with fixed contact 26. As shown in Figure 1, movable portion 24b of second bimetal member 24 is in the original state, that is, a state nearly colinear with base portion 24a, and contact point portion 24c of second bimetal member 24 is not in contact with bottom surface contact portion 28g of thermal resistive element 28.

When switch Sw is closed in this state, the current entering the first terminal (14) from power source E through switch Sw flows through fixed contact 26, movable contact 32, movable arm 30, and thermal resistive element 28 and away through second terminal 16 to motor M. Since current flows through this overcurrent protection device 10, joule heat (resistive heat) is generated at the various locations of the current path. In particular, the heat generated from thermal resistive element 28 is important. Hence, as to be explained later, the heat acts on first main bimetal member 34 and second bimetal member 24. Since resistance R of heating block 18 is much larger (by several hundred times) than the resistance value r of thermal resistive element 28, as long as the current flows in thermal resistive element 28 (when contacts 32, 26 are closed), heating block 18 acts as a virtual insulator, with no current flowing through it. Hence, no heating takes place in heating block 18.

As normal rated current  $I_R$  flows, the heat generated by thermal resistive element 28 accumulates in device 10, and the ambient temperature of device 10, in particular, the temperature of the winding of motor M, rises; hence, movable part 24b of second bimetal member 24 bends upwardly. When heating is carried out to a prescribed operating temperature, as shown in Figure 8, contact portion 24c of second bimetal member 24 comes in contact with bottom contact portion 28g of thermal resistive element 28. As shown in Figure 9, due to contact between these contact portions 24c, 28g, second bimetal member 24 is connected as a current bypass means in parallel with thermal resistive element 28. As a result, a portion of the current flowing through two contacts 26, 32 is diverted

to current bypass means 24, and the current flowing through thermal resistive element (28) is reduced significantly, for example, it may be halved. Consequently, even when rated current  $T_R$  continued flowing for a long period of time, the heating of thermal resistive element 28 can still be suppressed, and main bimetal 34 can maintain its original state.

With reference to Figure 12, if motor M is overloaded for some reason at time point t; the current rises drastically, the heat generated from thermal resistive element 28 increases, and the temperature of the winding of motor M also increases abnormally. As a result, first main bimetal member 34 snaps to its inverted position at the prescribed temperature, and it reaches the downward reversed state as shown in Figure 10. Consequently, the central portion of first bimetal member 34 moves into circular opening 28b of thermal resistive element 28, and thus, movable arm 30 moves so that movable contact 32 is separated from fixed contact 26. Since first bimetal member 34 is pressed by semispherical shaped protrusion portion 30b of movable arm 30, the inversion from the original state to the reversed state occurs in a single snap action.

In this way, since the circuit is cut off between two contacts 32, 26, no current flows in thermal resistive element 28. Instead, heating block 18 between first and second terminals 14, 16 acts as a thermal resistive element, and heating block 18 is heated to an electrical power of, for example, about 10 W. Due to the heating of heating block 18, the heating of main bimetal 34 continues even after cut off, and the reversed state shown in Figure 10 is maintained. For second bimetal member 24, due to heating by heating block 18, the contact state between thermal resistive element 28 and bottom contact portion 28 can be maintained. Or, due to the presence of thermal resistive element 28, the heat from heating block 18 does not significantly reach the second bimetal member, and the original state shown in Figure 1 may be recovered. In any case, the state of secondary bimetal 24 after cut off is not important to the operation of this overcurrent protection device 10, and any design may be adopted in this respect.

As explained above, since heating block 18 acts as a resistor, the current continues flowing in the electric circuit even after cut off between the two contacts 32, 26. Since the current I, is much smaller than the rated current, motor M virtually stops. When the user opens system switch Sw to service the motor, no current flows through this overcurrent protection device 10, the heating of heating block 18 stops, main bimetal 34 and secondary bimetal 24 return to their original positions, and movable contact 32 resumes its original orientation and is pressed in contact with fixed contact 26 (that is, the state shown in Figure 1).

In overcurrent protection device 10 of the present invention, the position of first bimetal member 34 is

switched, and connection/disconnection between fixed contact 26 and movable contact 32 is carried out. Consequently, the situation differs from that of the current-type fuse in that the same device can be used to cut off the overcurrent flow many times without the need of exchange of parts for each cut off operation. In addition, it has the self-holding breaker means since the cut off state is maintained due to the action of heating block 18 even after the overcurrent flow is cut off. That is, device 10 will not automatically reset after a cool down period as is standard in prior art protectors. Consequently, the protection of the electrical device or machine M can be maintained. In addition, when the rated current flows, the temperature near thermal resistive element 28 rises due to the accumulation of heat or the rise in ambient temperature. In this case, second bimetal 24 acts as a current bypass means since it is connected in parallel to thermal resistive element 28. In this way, the heating of thermal resistive element 28 can be suppressed, and faulty operation of first bimetal 34 can be prevented. Thus, there is no danger of cut off of contacts 32, 26 due to the faulty operation, and the reliability of the overcurrent protection device is greatly improved. Still further, first bimetal 34 is made of a circular plate shaped rebounding type bimetal, and first material 34 is energized by means of depression portion 30b of movable arm 30, so that main bimetal 34 can perform the reverse operation instantly, thus enabling high-speed snap-acting cut off.

In the above example, movable arm 30 and first bimetal member 34 are formed as separate parts, and movable arm 30 and movable contact point 32 are driven by main bimetal 34. However, it is also possible to form an integrated part with the main bimetal also acting as the movable arm. In the aforementioned example, second bimetal member 24 and the current bypass means are formed as an integrated part. However, it is also possible to form them as separate parts. It is also possible to use a single bimetal to act as both the first and second bimetal members. That is, the bimetals are so designed that they increase approximately linearly with the heating temperature. At the first displacement position, the bimetal is connected as a current means in parallel to the thermal resistive element. Then, at the second and larger displacement position, the movable contact point is separated from the fixed contact point. By changing the shapes and sizes of thermal resistive element 28 and concave portion 28f, it is possible to change the heating characteristics and response characteristics to the current as desired. It is also possible to connect thermal resistive element 28 in series with fixed contact 26, instead of the series connection with movable contact point 32. By replacing heating block 18 with a conventional insulating material, it is possible to form an automatic overcurrent protection device which can recover the original state after current-on

state soon after the cut off operation.

Accordingly, the overcurrent protection device of the present invention provides for a device which prevents the occurrence of a faulty condition when operation of the electrical circuit and machine are within rated operating conditions; and in the event of a faulty condition, maintains the cut-off (contacts open) until the circuit has been totally deenergized. Additionally, there is no requirement of new parts each time an electric circuit fault condition occurs.

It should be understood that although particular embodiments of this invention have been described by way of illustrating the invention, the invention includes all modifications and equivalences of the disclosed embodiments falling within the scope of the appended claims.

#### Claims

1. An overcurrent protection device comprising a fixed contact electrically connected to a first terminal, a movable contact connected to a second terminal adapted to engage and disengage with the fixed contact, a thermally resistive element connected in series to the fixed and movable contacts between the first and second terminals, a thermally responsive snap-acting first bimetal member positioned near said thermally resistive element which moves from a first position to a second position upon being heated to a first prescribed temperature, said second position causing the disengagement of said movable and said fixed contacts, a current bypass means adapted to be connected in parallel with said thermally resistive element, and a second thermally responsive bimetal member positioned near said thermally resistive element adapted to electrically connect said current bypass means in parallel with said thermally resistive element when heated to a second prescribed temperature lower than the first prescribed temperature associated with the first bimetal member.
2. The overcurrent protection device of claim 1 further including heating means adjacent said bimetal member connected between the first and second terminals.
3. The overcurrent protection device of claim 2 wherein said heating means has a resistance significantly higher than that of said thermally resistive element.
4. The overcurrent protection device of claim 2 wherein said heating means has a resistance at least about two hundred times that of said thermally resistive element.

5. The overcurrent protection device of claim 2 wherein said heating means is made from an electroconductive material having a relatively high resistance as compared to said thermally resistive element.
6. The overcurrent protection device of claim 1 wherein said second thermally responsive bimetal member is a bimetallic strip.
7. An overcurrent protection device comprising a fixed contact electrically connected to a first terminal, a movable contact connected to a second terminal adapted to engage and disengage with the fixed contact, a thermally snap-acting first bimetal member positioned near said thermally resistive element which moves from a first position to a second position causing the disengagement of said movable and said fixed contacts, a current bypass means connected in parallel with said thermally resistive element adapted to electrically connect said current bypass means in parallel with said thermally resistive element when heated to a prescribed temperature, and a heating means adjacent said first bimetal member connected between the first and second terminals, said heating means having a resistance significantly higher than that of said thermal resistive element.
8. The overcurrent protection device of claim 7 wherein said heating means has a resistance significantly higher than that of said thermally resistive element.
9. The overcurrent protection device of claim 8 wherein said heating means has a resistance at least about two hundred times that of said thermally resistive element.
10. The overcurrent protection device of claim 7 wherein said heating means is made from an electroconductive material having a relatively high resistance as compared to said thermally resistive element.

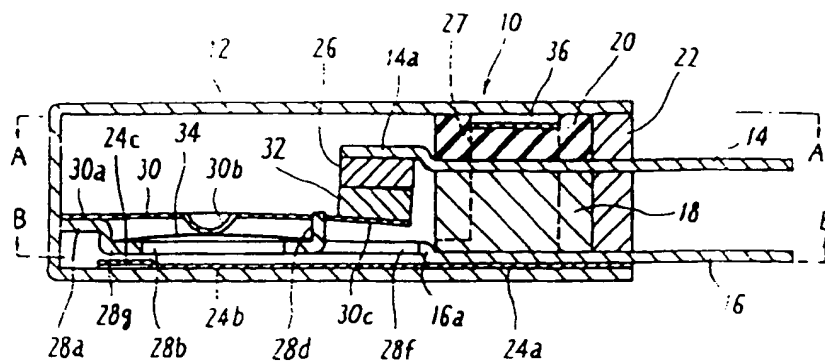


FIG. 1.

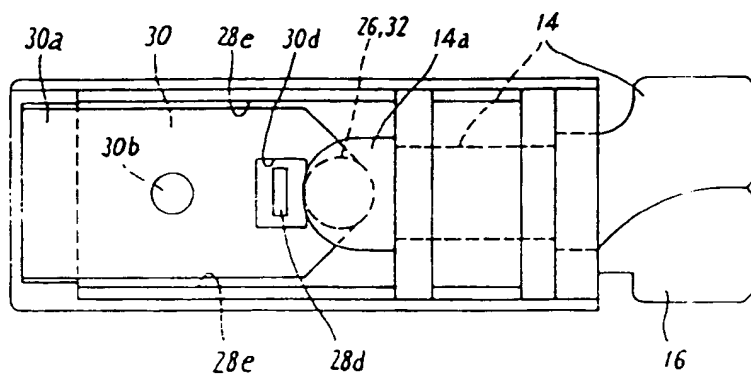


FIG. 2.

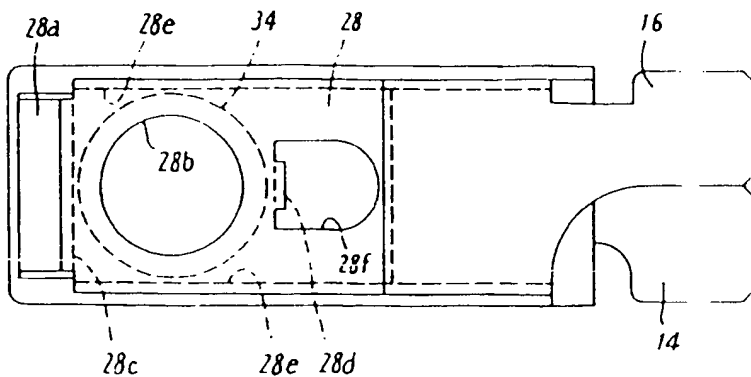


FIG. 3.

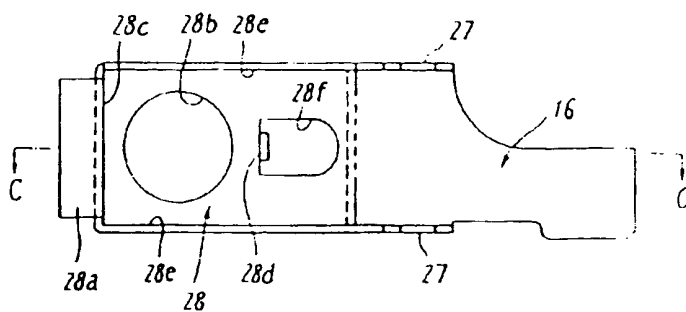


FIG. 4a.

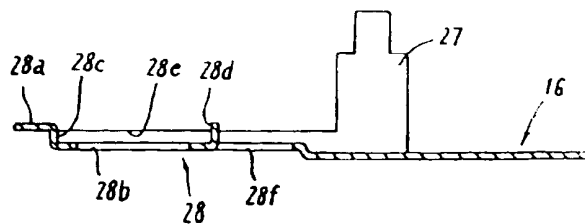


FIG. 4b.

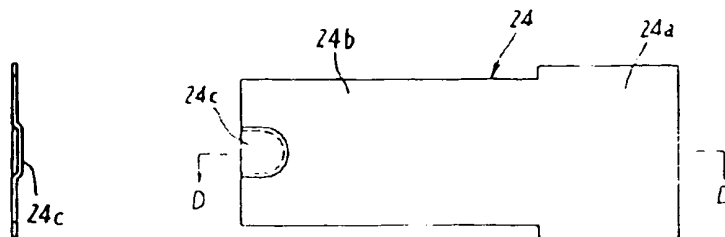


FIG. 5a.

FIG. 5b.



FIG. 5c.





FIG. 6a.



FIG. 6b.

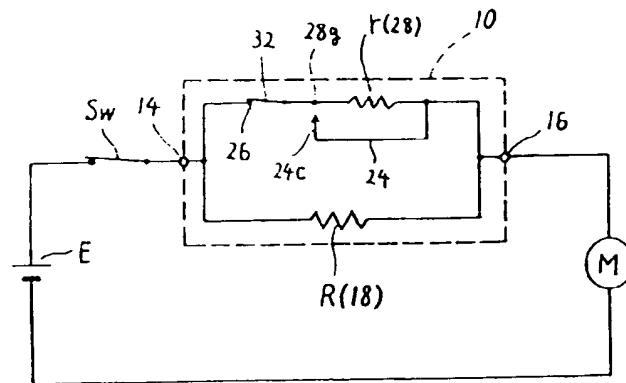


FIG. 7.

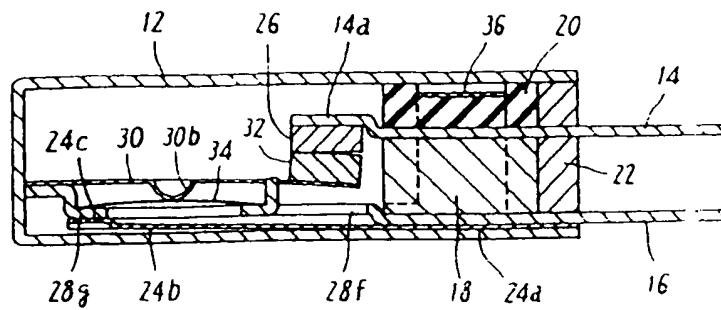


FIG. 8.

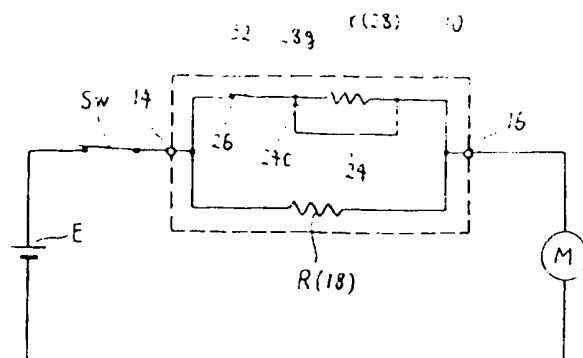


FIG. 9.

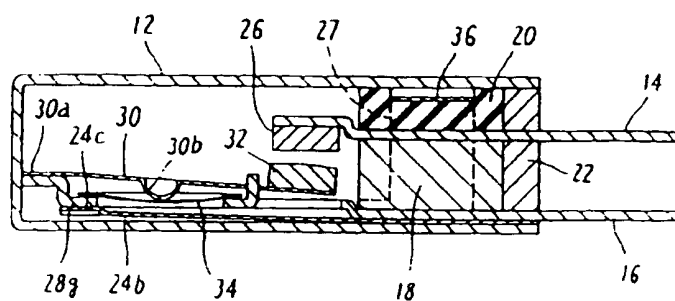


FIG. 10.

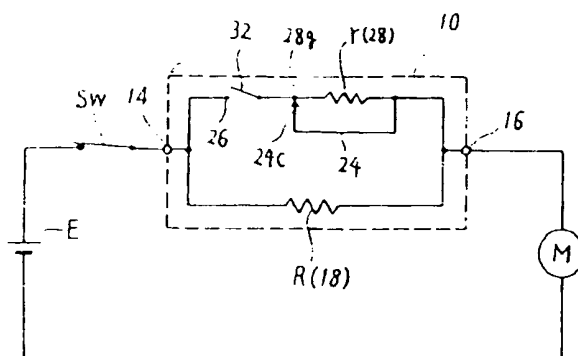


FIG. 11.

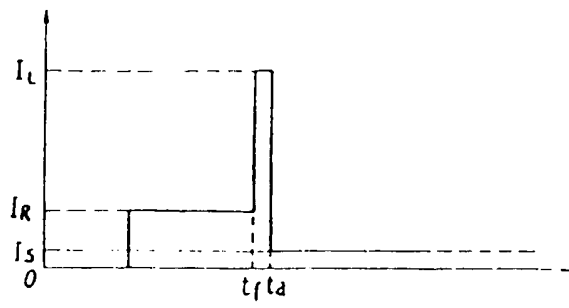


FIG. 12.

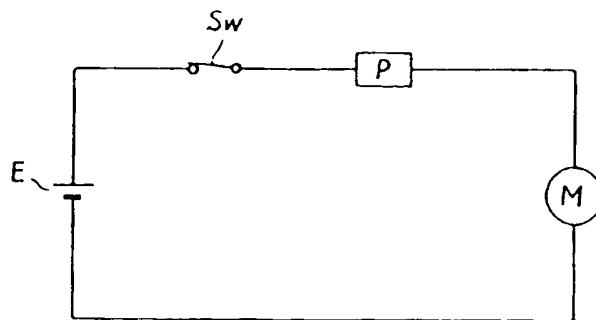


FIG. 13.

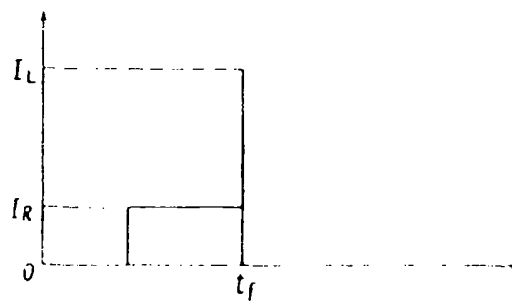


FIG. 14.



European Patent  
Office

# EUROPEAN SEARCH REPORT

Application Number

EP 93 30 2241

| DOCUMENTS CONSIDERED TO BE RELEVANT   |  |  |   |
|---|--|--|---|
| Category  | Citation of document with indication, where appropriate, of relevant passages                    | Relevant to claim  | CLASSIFICATION OF THE APPLICATION (Int. Cl.5) |
| Y   | FR-A-2 085 147 (TEXAS INSTRUMENTS INCORPORATED)<br>* page 3, line 3 - line 32 *                  | 1-10   | H01H71/16<br>H01H1/50                         |
| Y   | DE-C-703 412 (SIEMENS-SCHUCKERTWERKE)<br>* page 2, line 51 - line 98 *                           | 1-10   |   |
| A   | DE-U-6 913 999 (SWF-SPEZIALFABRIK FÜR AUTOZUBEHÖR GUSTAV RAU GMBH)<br>* page 5, last paragraph * | 1,7  |   |
|   |  |  | TECHNICAL FIELDS SEARCHED (Int. Cl.5)         |
|   |  |  | H01H  |
| The present search report has been drawn up for all claims  |  |  |   |
| Place of search<br>THE HAGUE  |  | Date of completion of the search<br>07 JULY 1993   | Examiner<br>LIBBERECHT L.A.                   |
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